

SELF-ENHANCING AND SELF-LIMITING EFFECTS DURING CO₂ LEAKAGE FROM GEOLOGIC DISPOSAL RESERVOIRS

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RESEARCH OBJECTIVES

The amounts of CO₂ that would have to be stored in geologic reservoirs are very large, and it appears inevitable that such plumes would encounter imperfections in the caprock, causing leakage. This raises a concern over whether it may be possible for a CO₂ leak to be self-enhancing, in such a way as to give rise to runaway discharge at the land surface with potentially serious consequences. CO₂ has physical properties—including lower density, much lower viscosity, and higher compressibility than aqueous fluids—which suggest that such a possibility should be taken seriously. The purpose of this research is to explore the behavior of leaking CO₂, and to identify conditions, if any, in which CO₂ could be discharged at the land surface in an eruptive manner.

APPROACH

Using information from natural systems, including CO₂ degassing in volcanic areas, and hydrothermal and pneumatic eruptions, we attempt to identify hydrogeologic conditions that would facilitate CO₂ discharge. Numerical simulations using our general-purpose simulator TOUGH2 and a special fluid property module for water-CO₂ mixtures were performed to study the behavior of proposed leakage systems that may involve supercritical as well as gaseous and liquid CO₂.

ACCOMPLISHMENTS

A 1 m thick vertical fault was prepared with initial conditions typical for continental crust (land surface conditions of 15°C temperature and 1 bar pressure; geothermal gradient of 30°C/km and hydrostatic pressures). Carbon dioxide was then introduced at a constant overpressure of approximately 9.5 bar relative to hydrostatic at a depth of 710 m. The CO₂ flows upward and outward from the injection point, displacing most of the water. Substantial cooling effects are observed as the CO₂ rises, caused by decompression and boiling of liquid CO₂ into gas. The interplay between multiphase flow and heat-transfer effects causes nonmonotonic discharge behavior at the land surface (see Figure 1). The strong feedback between fluid flow and heat transfer tends to limit CO₂ fluxes, gives rise to quasi-periodic variations in flow rates, and makes it difficult to envision scenarios in which leakage of CO₂ as a free phase could develop a self-enhancing runaway discharge at the land surface.

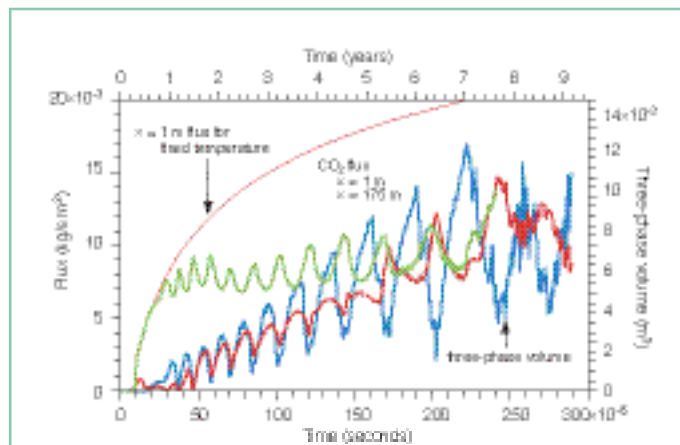


Figure 1. CO₂ discharge behavior from a fault zone. The curves labeled "1 m" and "175 m" show simulated leakage fluxes at the land surface at 1 m and 175 m lateral offset, respectively, from the injection point along the fault strike. Flux predictions obtained for a simulation in which temperatures are held constant at initial values are also shown for comparison. The blue curve shows total fault zone volume in three-phase conditions (aqueous-liquid CO₂-gaseous CO₂).

SIGNIFICANCE OF FINDINGS

Leakage of CO₂ along a fault or fracture zone is accompanied by strong cooling effects. These effects limit CO₂ discharge rates and give rise to nonmonotonic leakage behavior.

RELATED PUBLICATION

Pruess, K., Numerical studies of fluid leakage from a geologic disposal reservoir for CO₂ show self-limiting feedback between fluid flow and heat transfer. *Geophys. Res. Lett.*, 32 (14), L14404, doi:10.1029/2005GL023250, 2005. Berkeley Lab Report LBNL-57362.

ACKNOWLEDGMENTS

This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

